PATERSON TEMPEST AEM SURVEY
Data Acquisition, Processing, and Inversion

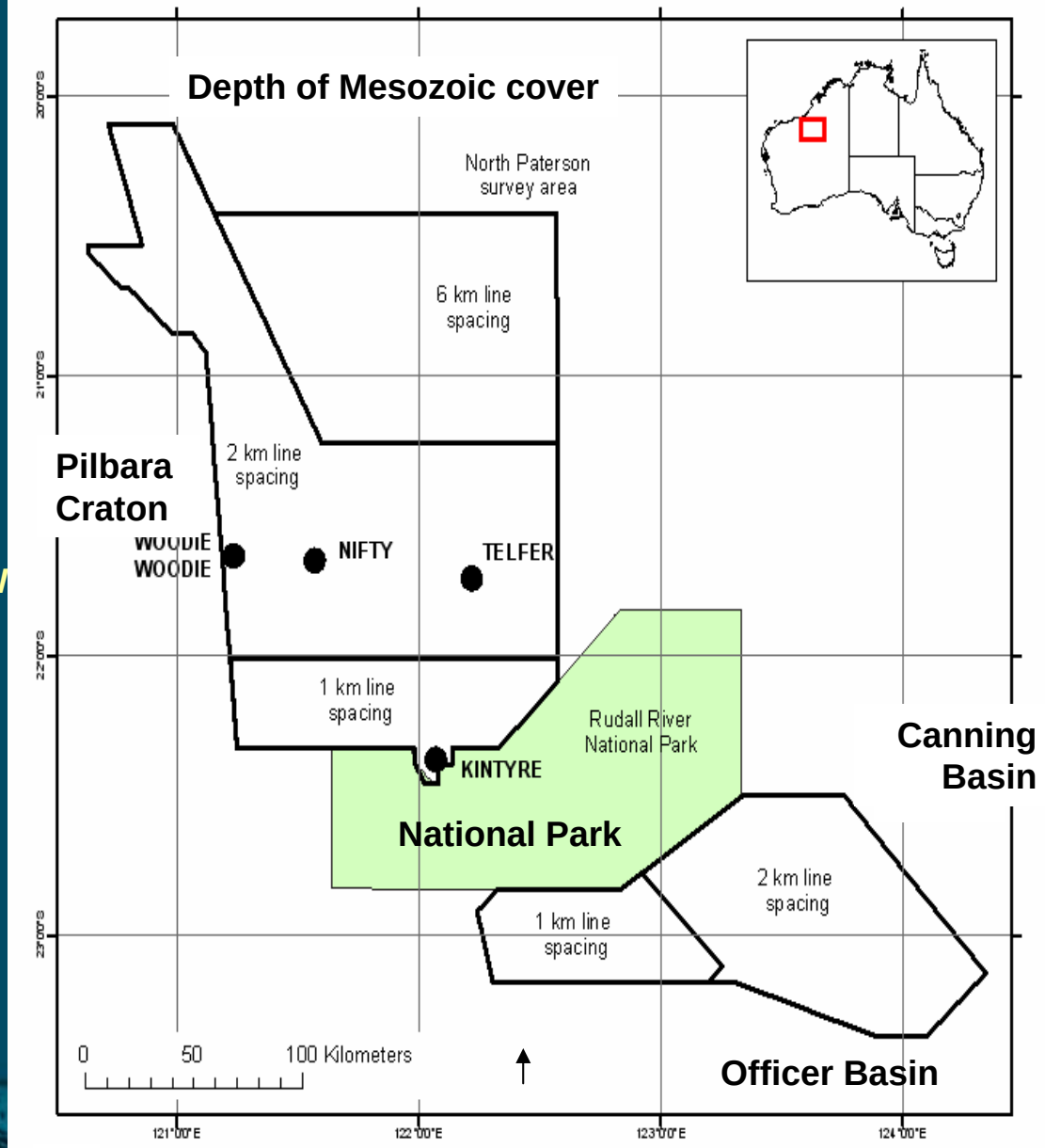
Marina Costelloe

With contributions from Ian Roach, David Hutchinson and Camilla Sorensen

Onshore Energy and Minerals Division

PATERSON AEM SURVEY

Coverage	47 600 km2
Total Kilometres	28 200 line km
Line Spacing	
Deposit Scale	200m 1000 m
Regional Scale	2000 m 6000 m
Line Direction	North Paterson E-W
Line Direction	South Paterson NE-SW
Infill Companies	5
Investment (approx)	$4 million



121°0'0"E
122°0'0"E
123°0'0"E
124°0'0"E
20°0'0"S
21°0'0"S
22°0'0"S
23°0'0"S

Rio Tinto

Cameco

Mega Uranium

Rudall River
National Park

Well 33
(100 km away)

Parnngurr

Scimitar

Western Areas

N

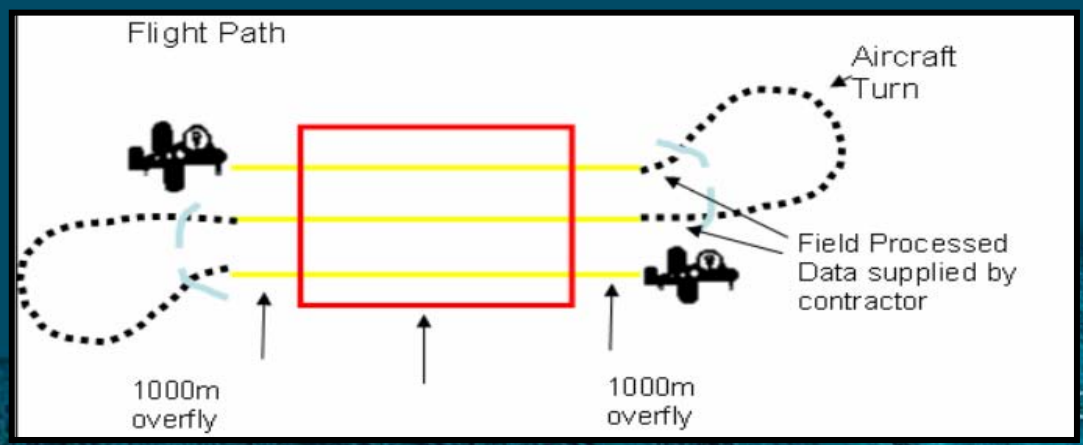
0 30 60 120 Kilometers

Flight path over gravity

Data Acquisition

TEMPEST – Fugro Airborne Surveys

fixed wing time domain system



Survey Timing

Milestone	
Pre-Survey planning started	Jan-07
Flying commenced South Paterson	Oct-07
Flying completed South Paterson	Nov-07
Flying Recommenced North Paterson	May-08
Flying completed North Paterson	Oct-08
Final data received from Contractor South Paterson	Jan-09
Final data received from Contractor North Paterson	Apr-09
Final data South Paterson *RELEASED*	Mar-09
Final data North Paterson *RELEASED*	Apr-09

Purpose

Provide geoscience data to encourage energy and mineral exploration in Australia

Feature	Paterson
Depth to Basement	✓
Basement Structures	✓
Regolith Mapping	✓
Graphitic Units in the Basement	✓
Location and Morphology of Paleovalleys	✓
Hydrogeological Elements	✓

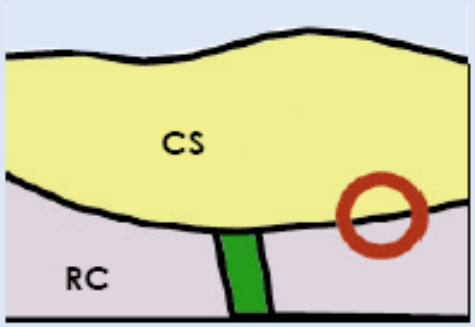
Detecting these geological features reduces exploration risk

Forward Modelling

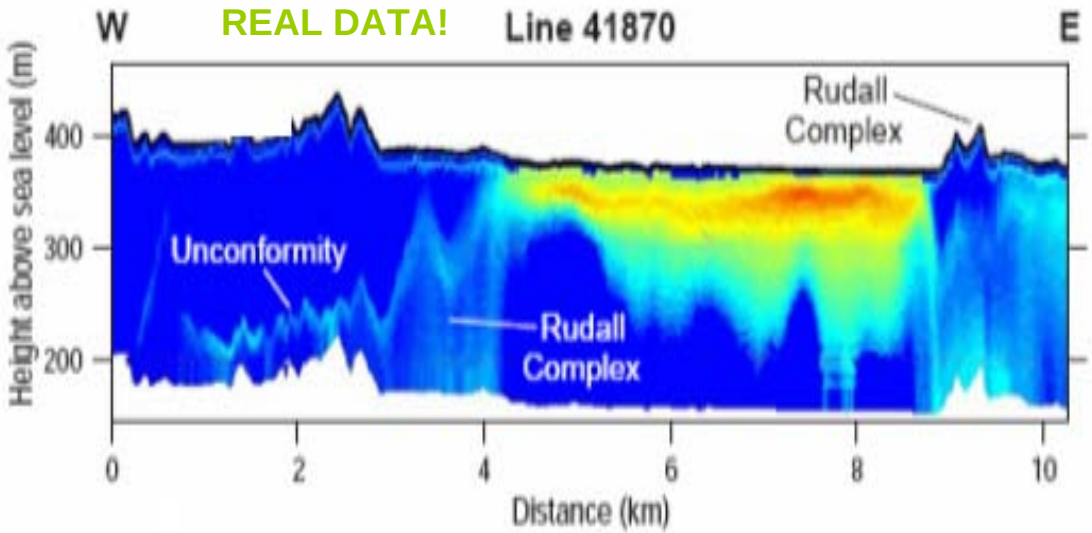
Determining the probability of detection of a geological target

Model 1; Coolbro Sandstone overlying the Rudall complex

Geological model



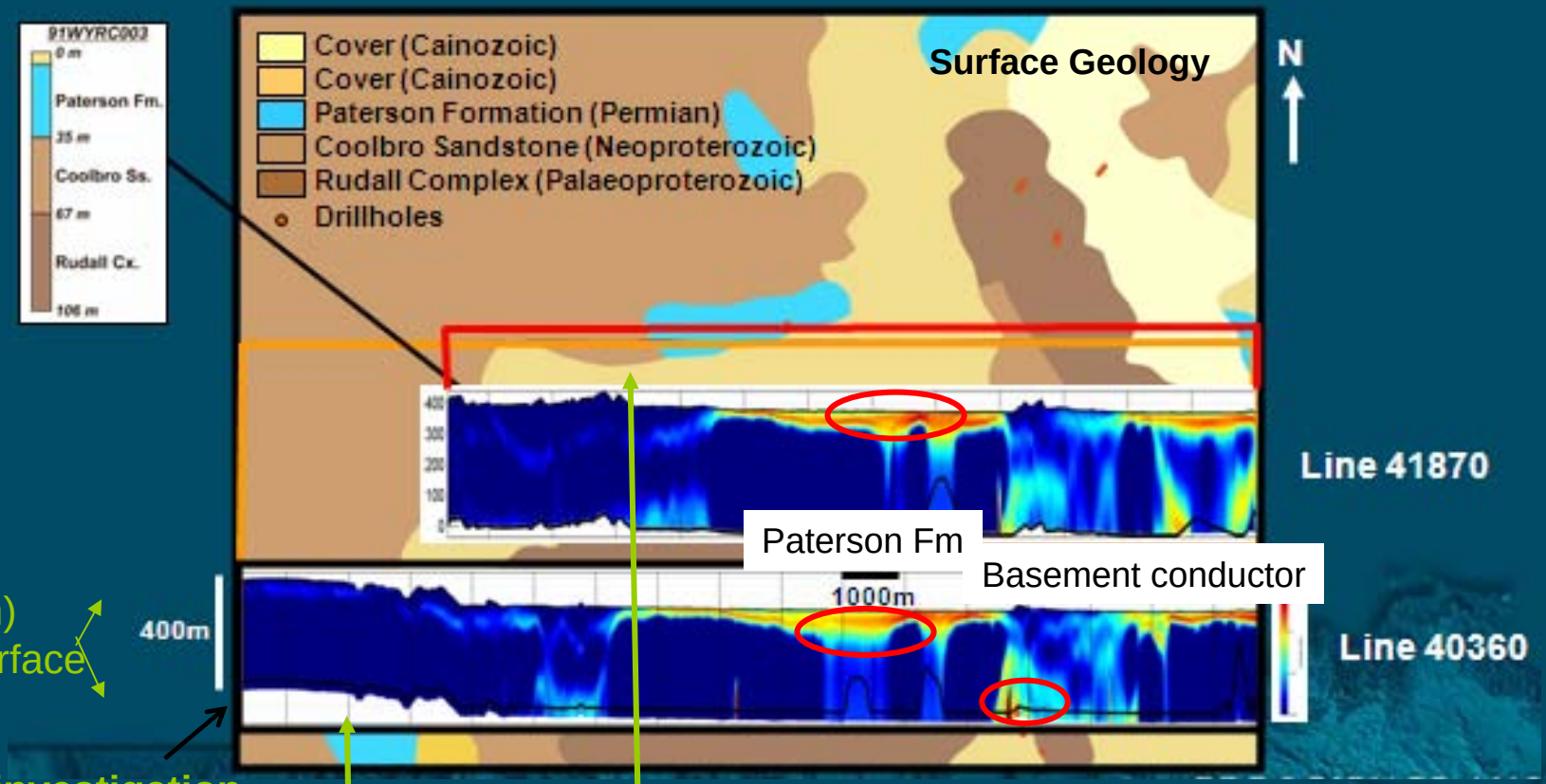
REAL DATA!



This model had a low probability of detection … BUT theoretically it was possible

Forward Models – Real Data

Geoscience Australia Layered Earth Inversion sections over surface geology



The Truth is in the Drilling

Short Article

AEM survey detects major unconformity

Feature Paper

Paterson AEM survey directly detects major unconformity near Kintyre, WA

Marina Costelloe

Marina T. Costelloe[1,2], Ian C. Roach[1] and David K. Hutchinson[1]

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Introduction

Geoscience Australia flew a regional Airborne Electromagnetic (AEM) survey across the Paterson Province of Western

- the unconformity was anticipated to have a complex structural nature because of post-depositional tectonics; and
- reports indicated that the alteration zone at the unconformity may not have sufficient conductivity to be measured.

Evidence for the Coolbro–Rudall unconformity

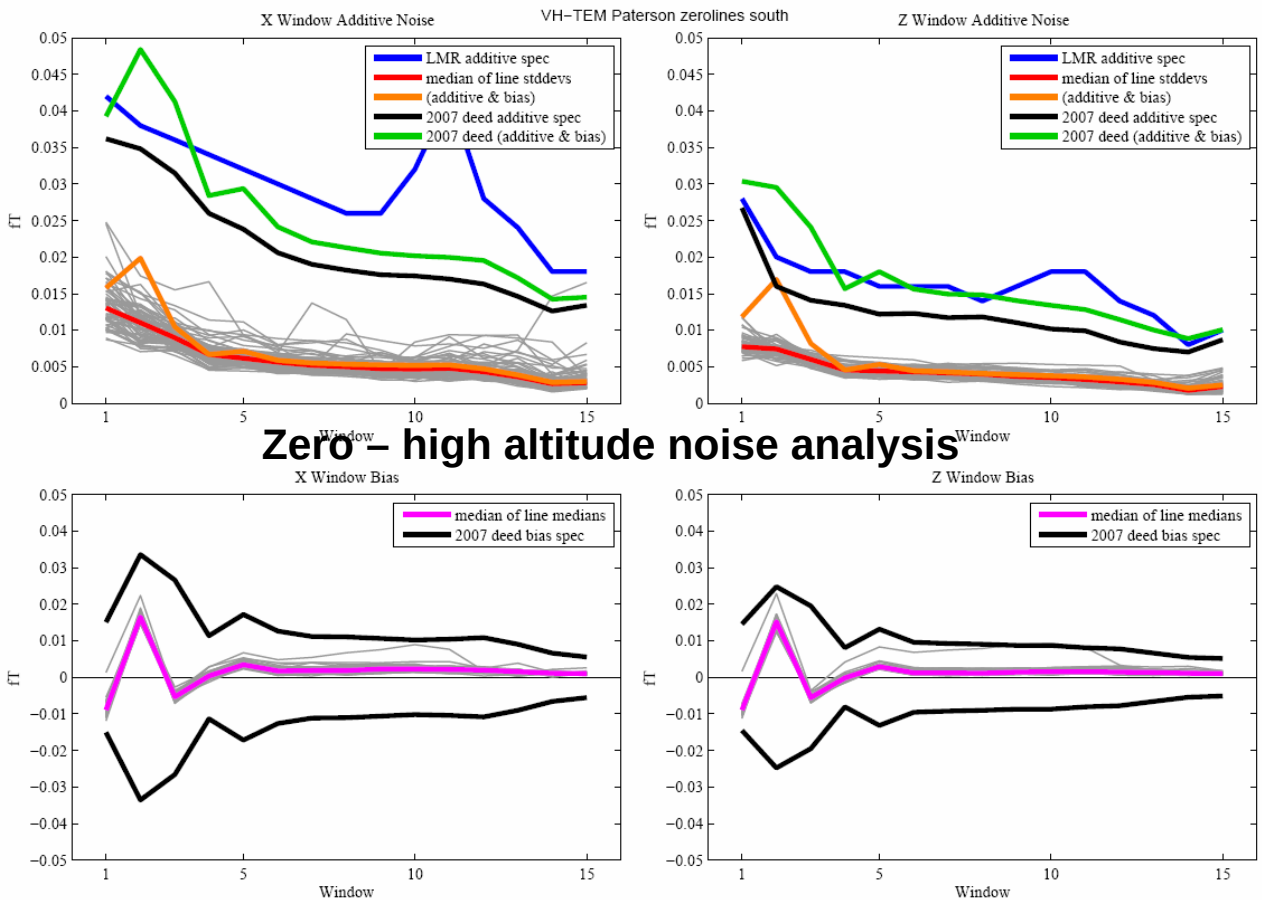
AEM data were interpreted using an integrated approach incorporating the Geoscience Australia 1:1 000 000 Surface Geology of Australia map (Stewart, 2008), solid geology (Czarnota, *et al.* 2009), publicly available drill hole logs (Roach, 2009) and the results of the layered earth inversion process developed by Geoscience Australia (GA LEI; Lane, *et al.* 2004). The investigation focused on areas where surface mapping indicated that the Coolbro–Rudall unconformity was expected to lie under cover.

Figure 1 shows GA LEI conductivity depth sections for three consecutive 200m spaced flight lines proximal to the Coolbro–Rudall unconformity, as geologically mapped near the Kintyre uranium deposit, which lies about 4 km off-section to the east. The depth of investigation line, which normally features on conductivity depth sections, is below the data depicted in these

Data Processing QA/QC

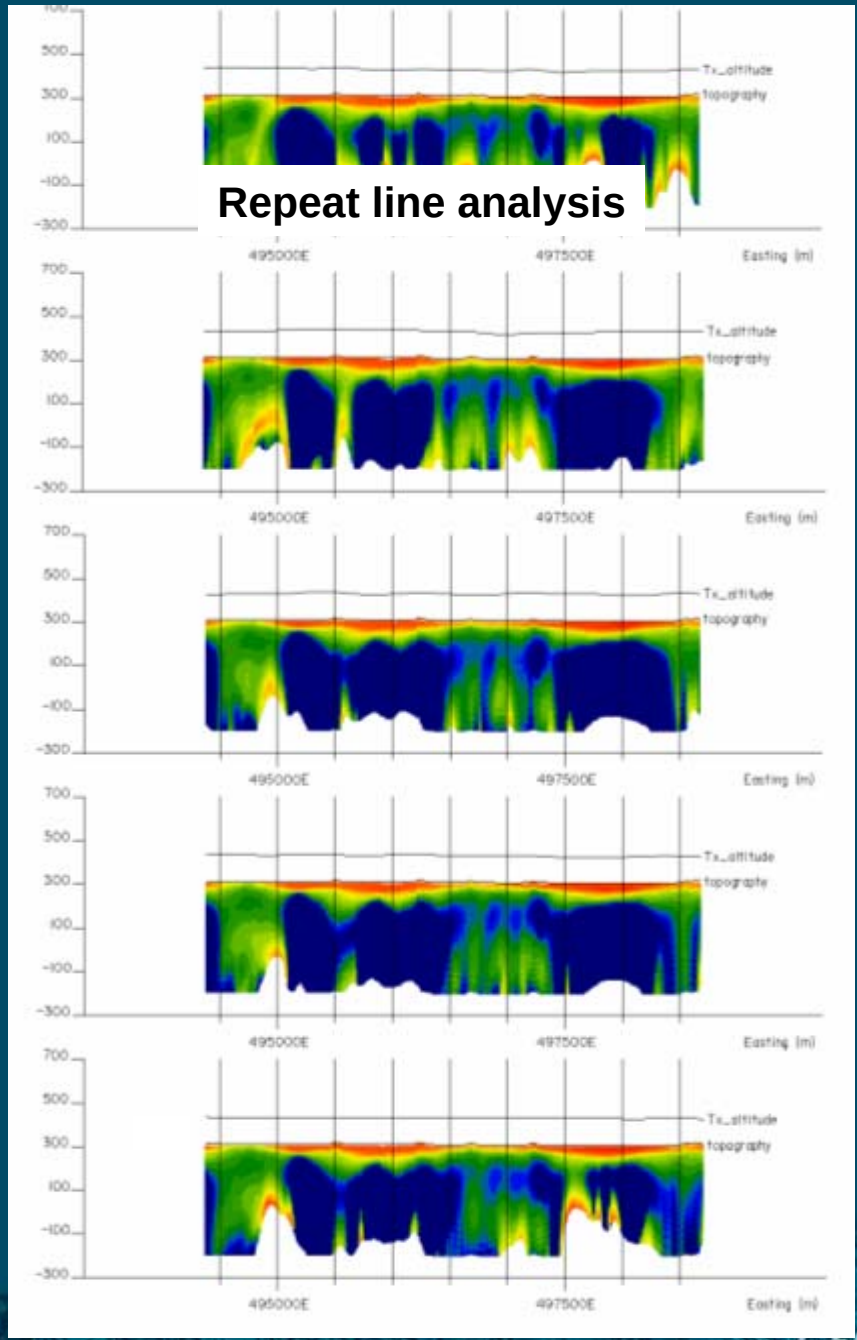
- Data Fields
- Flight path
- Terrain Clearance
- Altimeters
- Noise Analysis
- Statistics
- Metadata
- Logistics
- Base Station Data
- Communication

Nulls, level shifts, coherency, noise, interpretability….



Zero – high altitude noise analysis

- Data Fields
- Flight path
- Terrain Clearance
- Altimeters
- Noise Analysis
- Statistics
- Metadata
- Logistics
- Base Station Data
- Communication



- Data Fields
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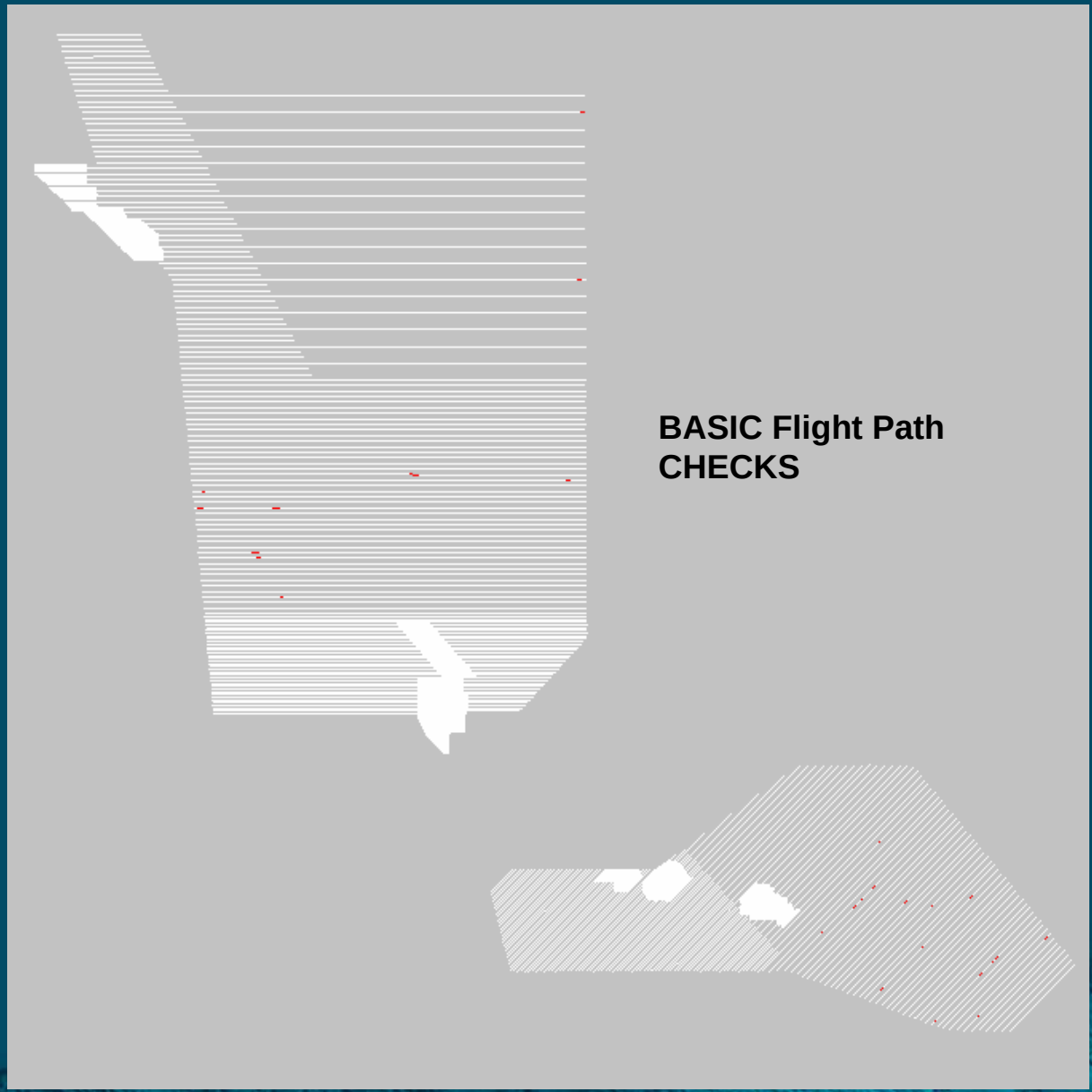


Multiplots

System Geometry

Noise monitors and Sferics (X)

X component data

Noise monitors and Sferics (Z)

Z component data

EMFlow CDI

Magnetics

Multiplots

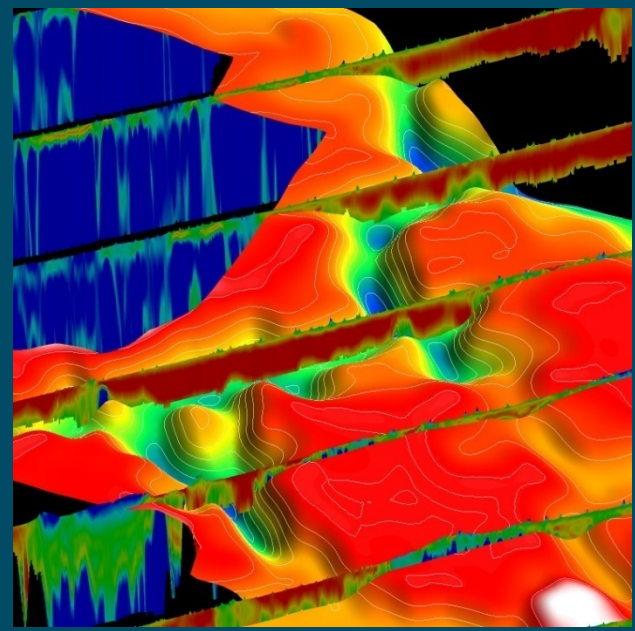
They are used in QA/QC, to assess noise, pick basement conductors, viewing conductivity edges…..

Contiguous line by line assessment

Fit For Purpose

The accuracy, integrity and useability of AEM data are reliant upon

- **flight height**
- **system geometry**
- **noise**
- **repeatability**



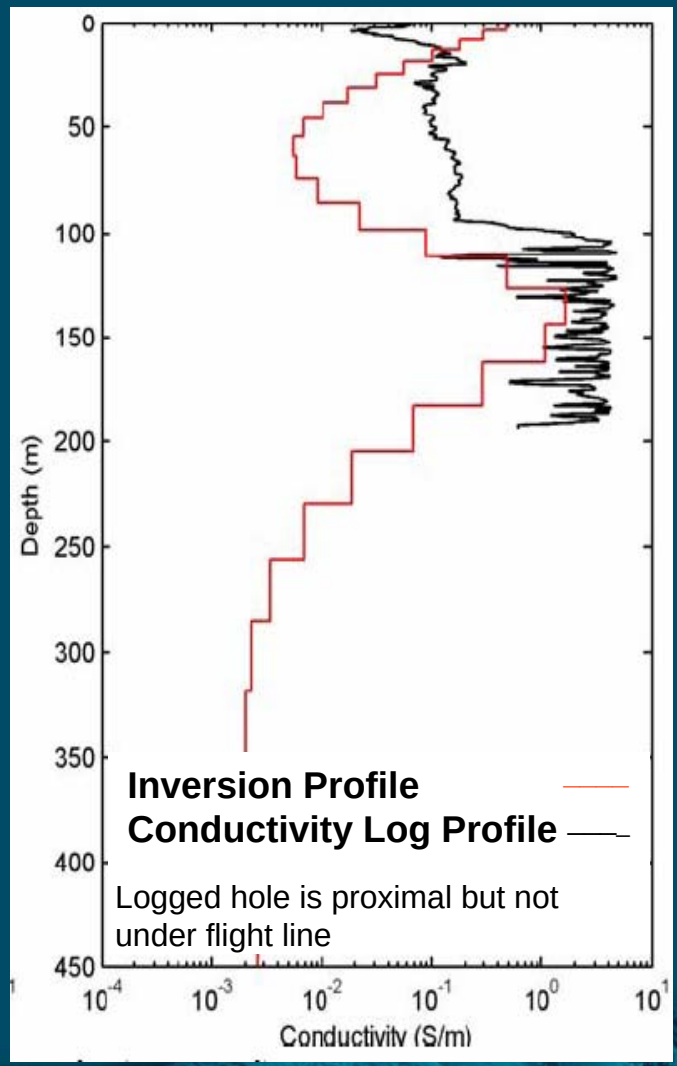
The AEM data is of acceptable standard to be interpreted, inverted and manipulated

Induction Conductivity Logging

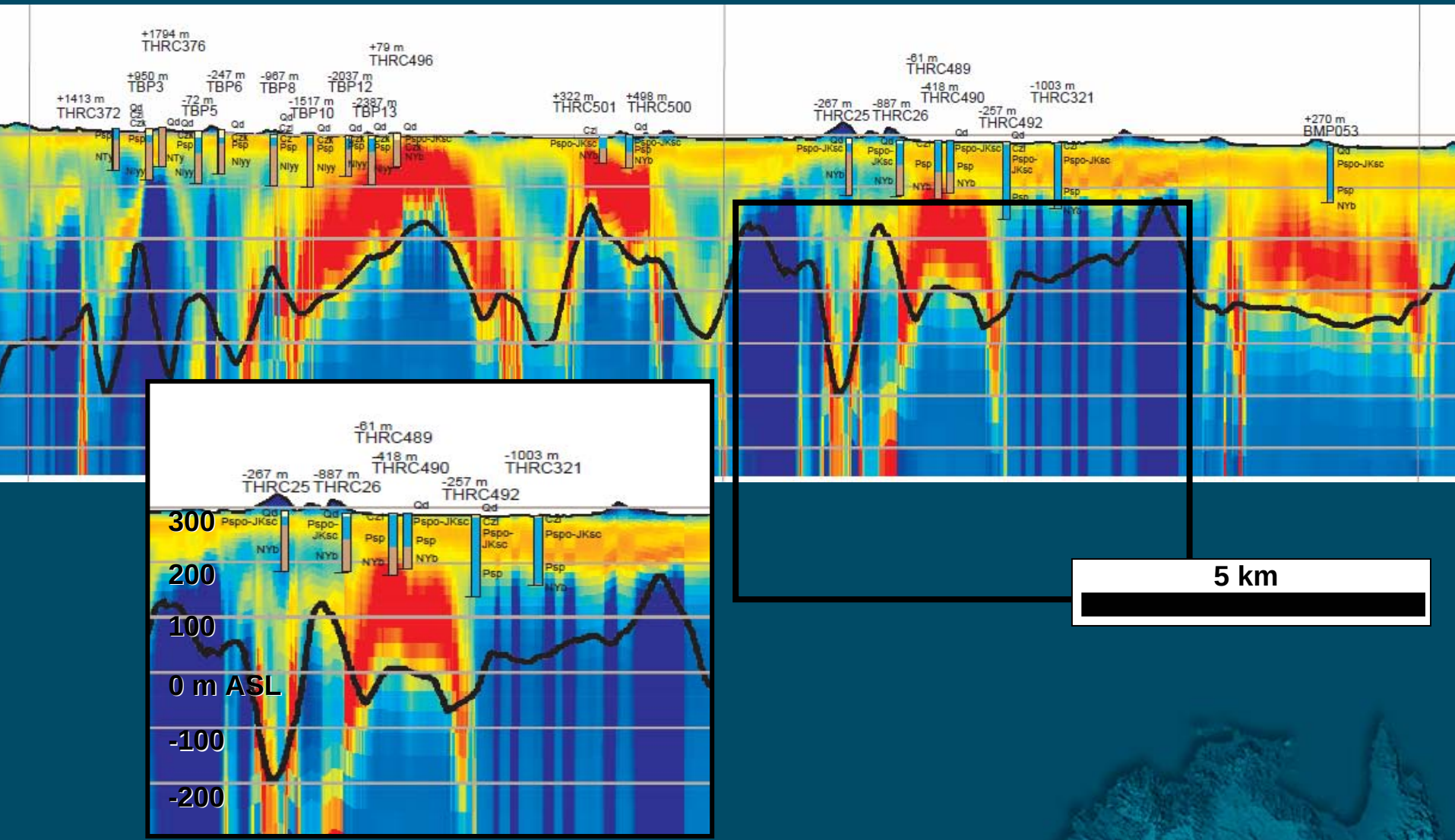
Feed into forward models
Ground truth AEM results
Use for geological interpretation

John Jaycock and Camilla Sorensen logging in north Paterson, September 2008. Photo by Pauline English.

Conductivity log compared to GA LEI

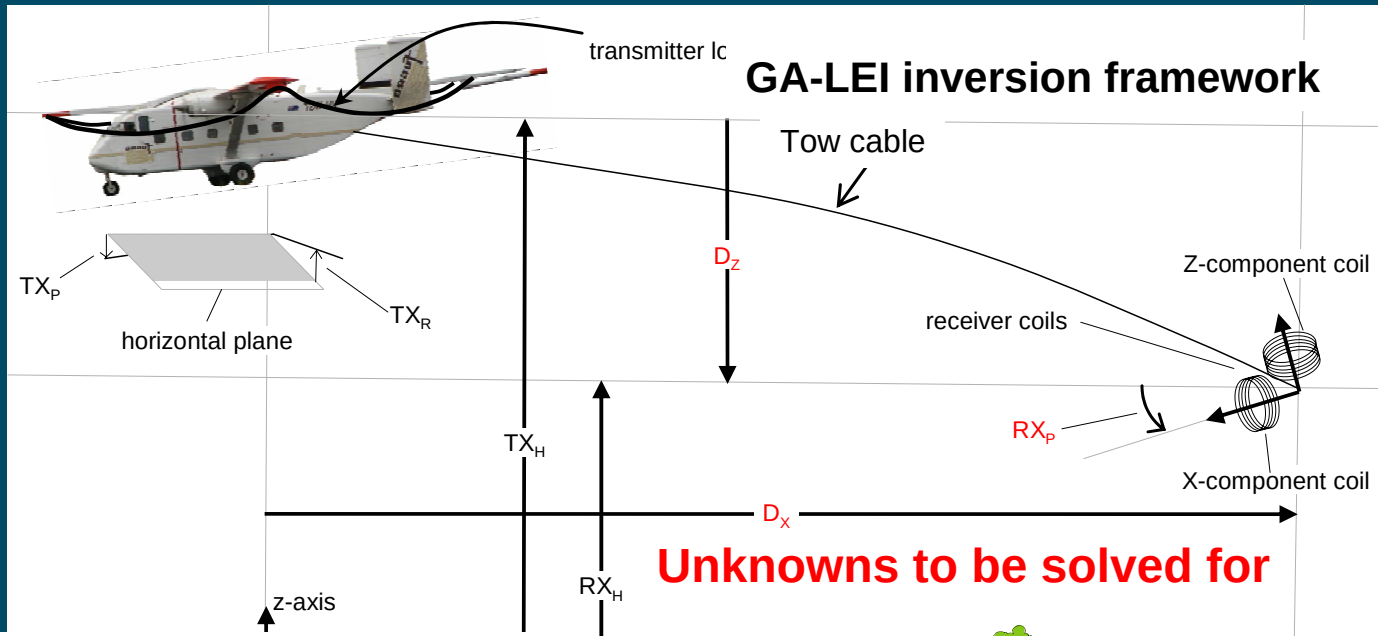


Drill holes vs GA-LEI



Geoscience Australia Layered Earth Inversion

GA-LEI



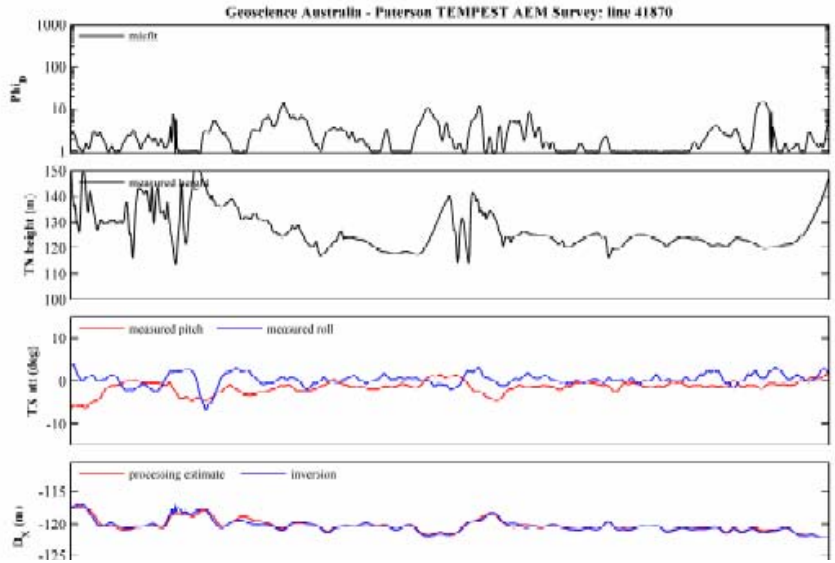
Solves for conductivity and the unmeasured elements of the system geometry
using the observed total field X and Z component data

	$c_1=10^{lc_1}$	μ_0	ε_0	$t_1=10^{lt_1}$
	$c_2=10^{lc_2}$	μ_0	ε_0	$t_2=10^{lt_2}$
	...	...	...	...
layer N_L-1	$c_{N_L-1}=10^{lc_{N_L-1}}$	μ_0	ε_0	$t_{N_L-1}=10^{lt_{N_L-1}}$
layer N_L1	$c_{N_L}=10^{lc_{N_L}}$	μ_0	ε_0	$t_{N_L}=\infty$

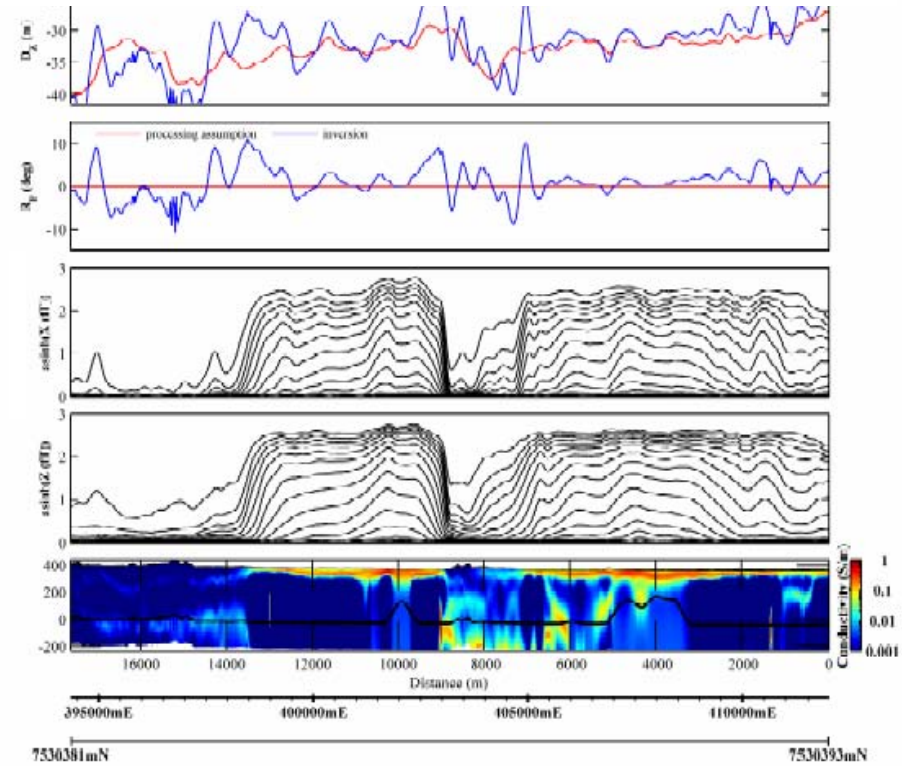
Slide provided by Ross Brodie

GA LEI Multiplot

Phi_d	Data misfit
TX Height	Transmitter height
TX Attitude	Transmitter attitude
D_x	In line horizontal sep
D_z	In line vertical sep
R_p	Receiver pitch in degrees
X and Z	Window Amplitude
GA-LEI	Section

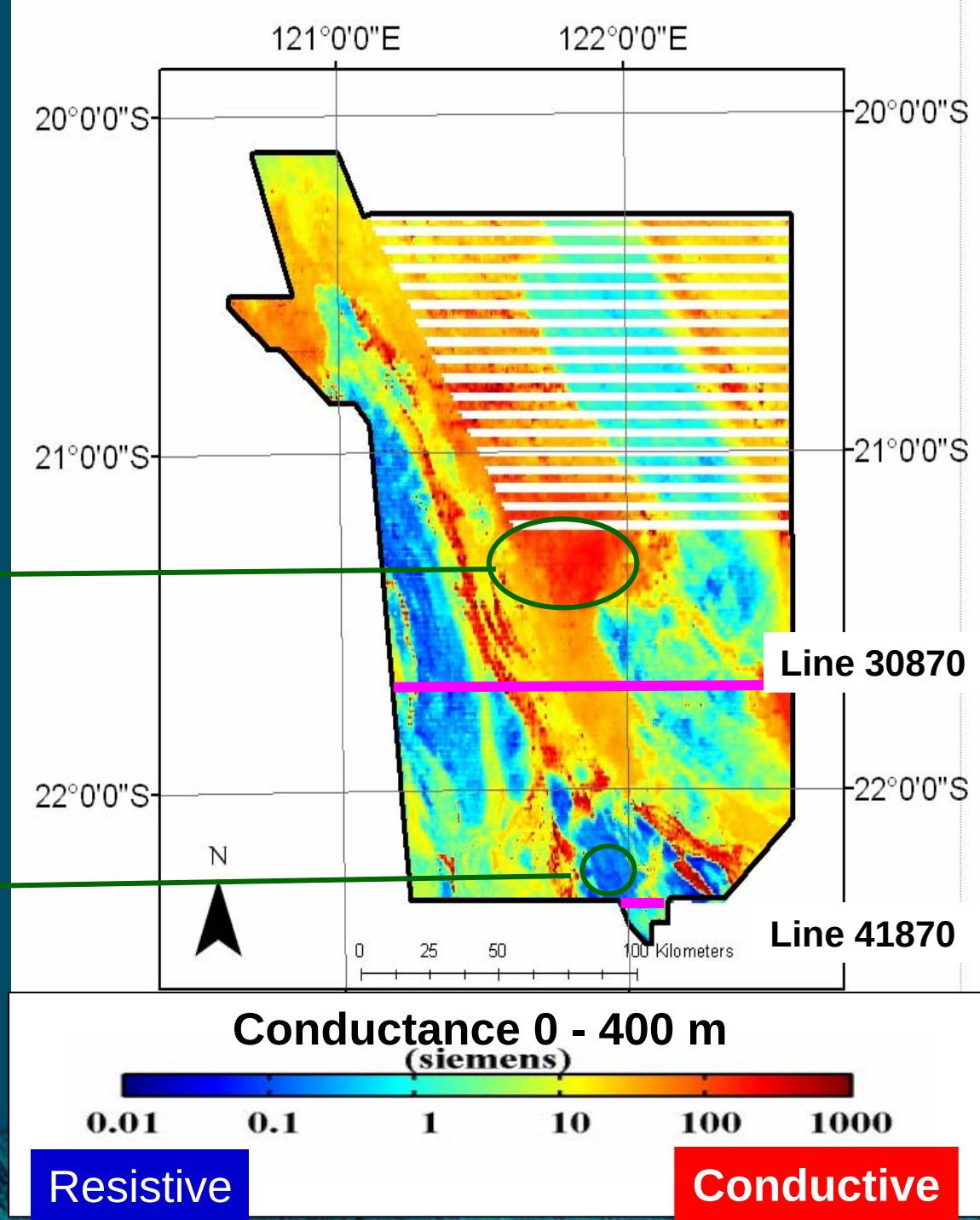


Processing estimate and inversion output



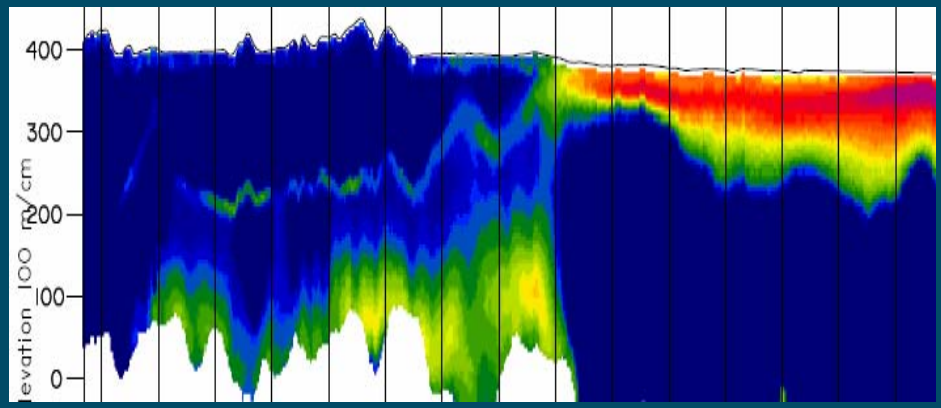
Conductance

30 layer GA-LEI
Start Model 0.004 S/m
Reference model 0.004 S/m

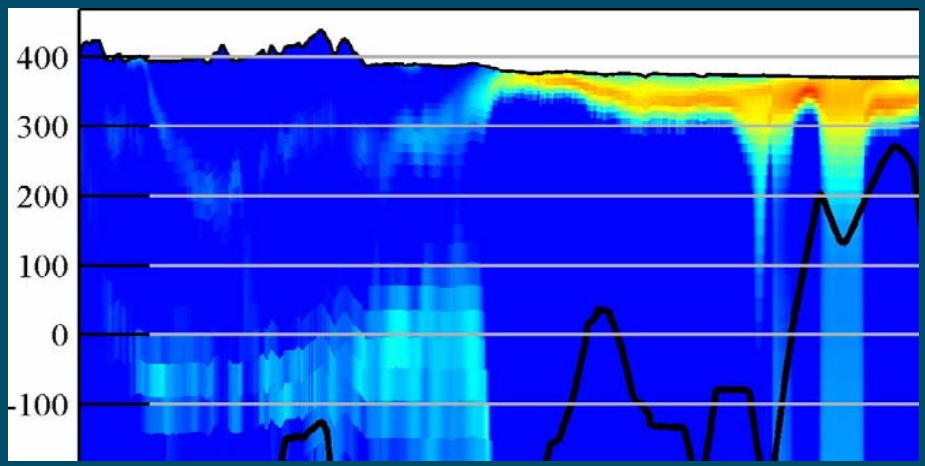


EMFlow and GA LEI

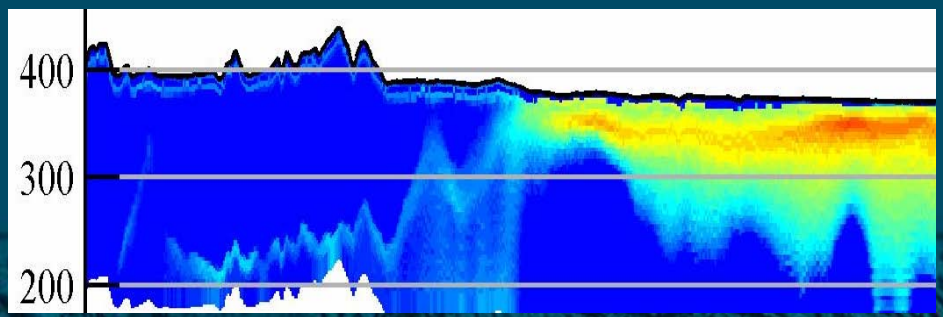
Both highlight the unconformity between the Coolbro Sandstone and Rudall Complex



EMFlow over 300m
(provided by Fugro)

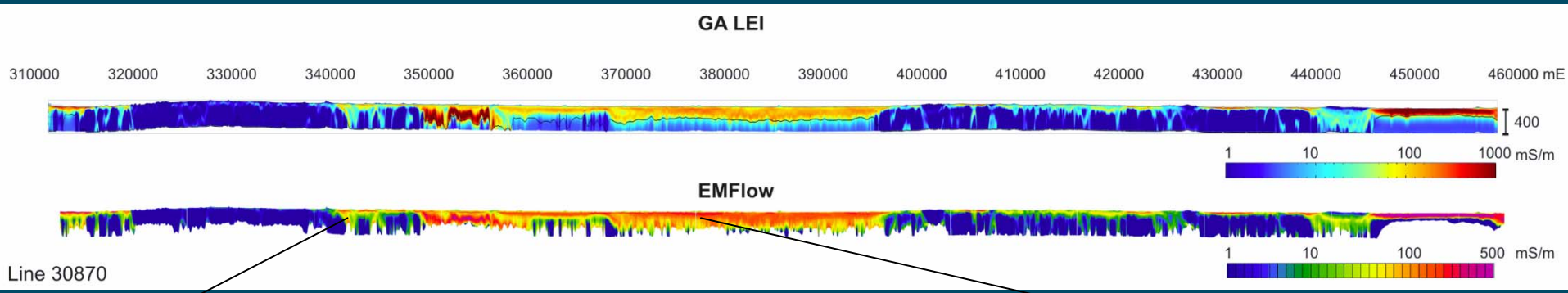


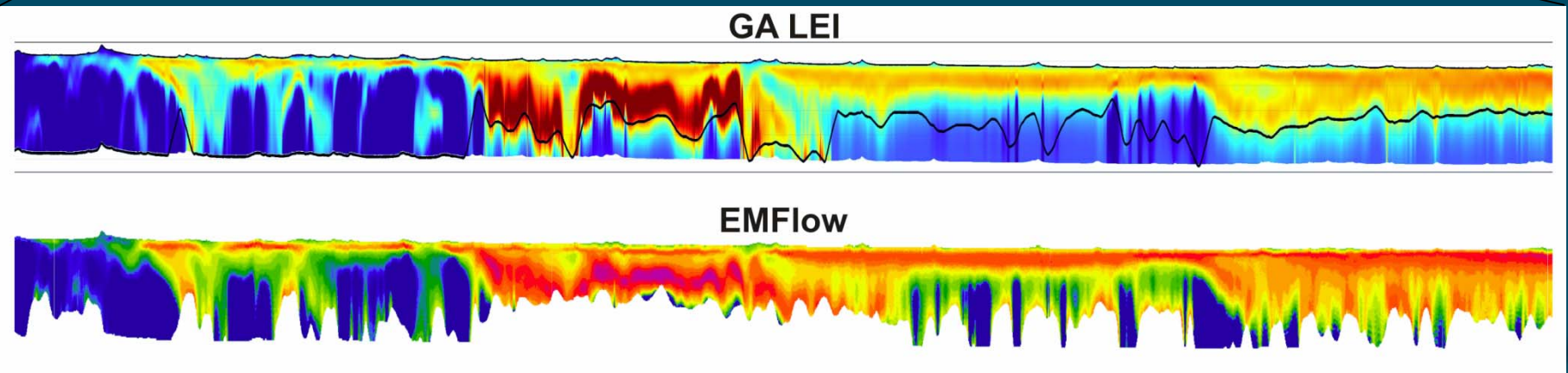
GA-LEI
30 layers over 500m



GA-LEI
30 layers over 200m

EMFlow and GA-LEI





Products

Phase 1 Contractor supplied

GA funded data Released 2009

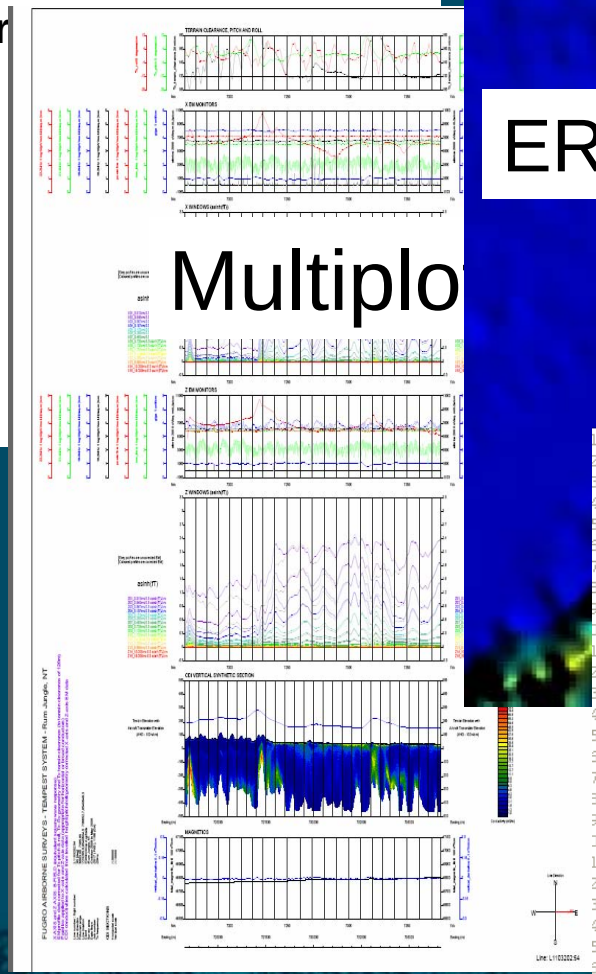
Infill company funded data r

Logistics report

ASCII data

Multiplots with EMFlow

Gridded data



Multiplo

ERMapper Grids

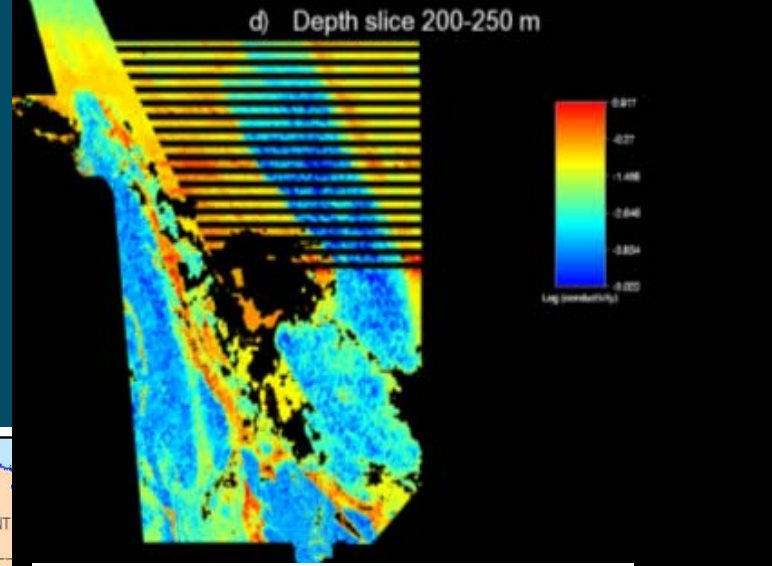
```
COMM GA PROJECT NUMBER ..... 1168
COMM FAS PROJECT NUMBER ..... 1896
COMM AREA NUMBER: ..... 3, 31, 32, 4, 41, 42, 43
COMM SURVEY COMPANY: ..... Fugro Airborne Surveys
COMM CLIENT: ..... Geoscience Australia
COMM SURVEY TYPE: ..... 25Hz TEMPEST Survey
COMM AREA NAME: ..... Paterson North
COMM STATE: ..... WA
COMM COUNTRY: ..... Australia
COMM SURVEY FLOWN: ..... November 2007 to October 2008
COMM LOCATED DATA CREATED: ..... December 2008
COMM
COMM DATUM: ..... GDA94
COMM PROJECTION: ..... MGA
COMM ZONE: ..... 51
COMM
COMM SURVEY SP
COMM
COMM TRAVERSE ..... 200-6000 m
COMM TRAVERSE ..... 090-270 deg
COMM NOMINAL T ..... 120 m
COMM FINAL LIN ..... 19384.92 km
COMM
COMM LINE NUMBERING
COMM
COMM TRAVERSE LINE NUMBERS: ..... 30010 - 31970
COMM ..... 40010 - 43780
COMM ..... 10000
COMM SURVEY EQUIPMENT
```

METADATA VIP for data exchange and archiving

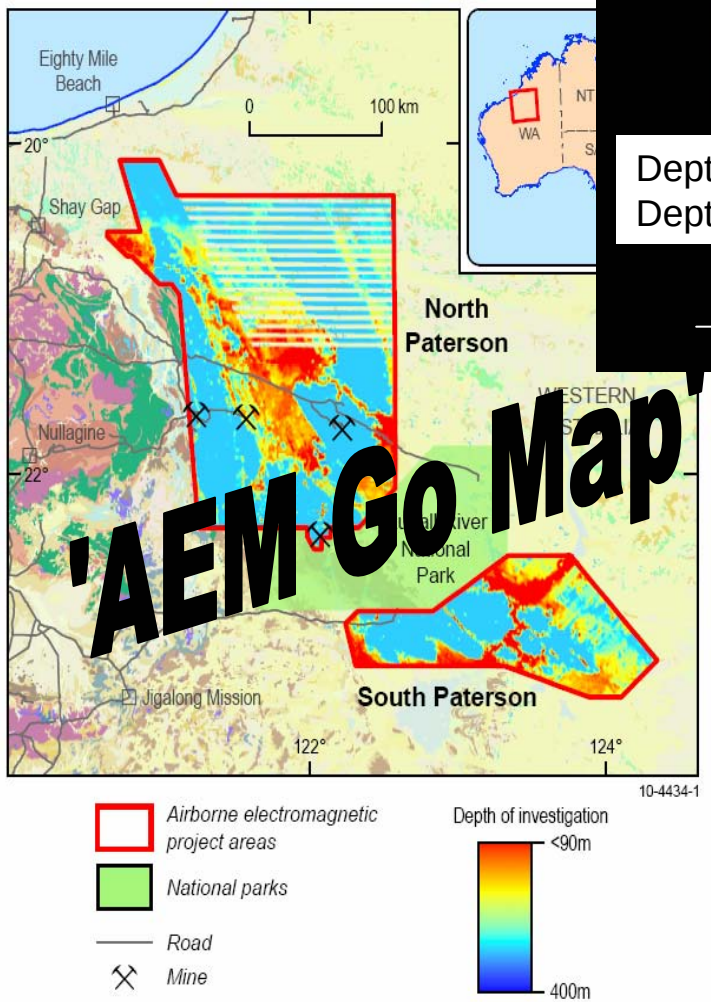
Phase 2

GA LEI and enhance products
Released April 2010
ASCII Data Conductance
ASCII Data Elevation Slices
Grid Total Conductance
Grids Elevation slices (Sea Level)
Grids Depth Slices (Topography)
Geo-referenced GA LEI cross-sections
Geo-referenced Grid jpegs
AEM GO MAP
Report

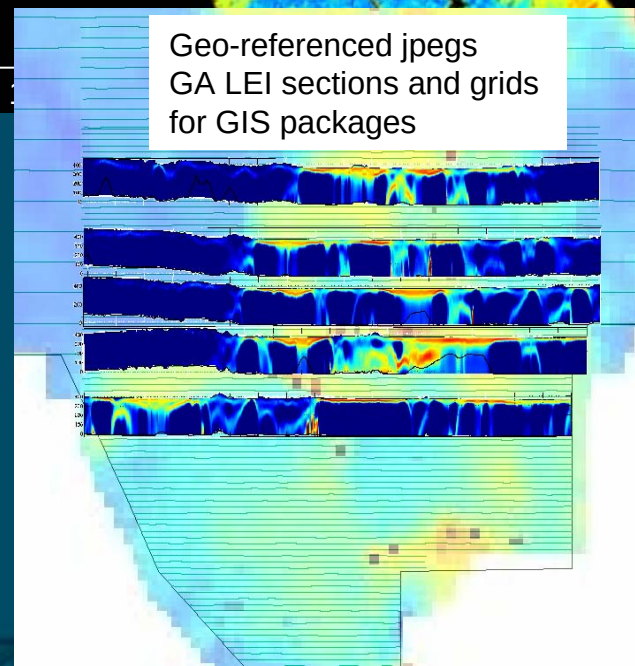
Products



Depth slice grids
Depth of Investigation blanked out



'AEM Go Map'



Geo-referenced jpegs
GA LEI sections and grids
for GIS packages

… and metadata

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Airborne Electromagnetics Project

Overview

Under the Australian Government's Onshore Energy Security Program, Airborne Electromagnetic (AEM) data are being acquired in areas considered to have potential for uranium or thorium mineralisation.

The surveys, which are part of the Airborne Electromagnetic Acquisition and Interpretation project, are designed to reveal new information about regions by acquiring the AEM data at line spacings of one to six kilometres over relatively large areas. The improved understanding of the regional geology resulting from the surveys will be of considerable benefit to mining and mineral exploration companies, who can obtain more detailed data over a specific area of interest by contributing additional funds to the acquisition cost.

AEM project areas
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As a result of reviews of AEM system capabilities and relevance to energy commodities, acquisition is directed principally at providing geophysical and inferred geological insights in areas considered to be prospective for unconformity related and palaeochannel hosted uranium.

As well as enhancing the search for uranium and other energy sources, the survey results will be relevant in exploration for a variety of commodities and other resources, including groundwater. The program is aimed at reducing exploration risk and promoting exploration activity. Three priority projects emerged from mineral systems analysis and discussions with the State and Northern Territory Geological Surveys. They are:

1. Paterson Province (Western Australia)
2. Pine Creek (Northern Territory)
3. Frome Embayment - Murray Basin (South Australia)

aem@ga.gov.au

Status

The objectives and status of the three priority projects are:

Project 1 - Paterson Province, Western Australia

The Paterson project is centred on the Kintyre uranium deposit and covers much of the surrounding exposed and near surface Paleoproterozoic Era Rudall Complex which in the surrounding area is unconformably overlain by Neoproterozoic Era sediments of the Yeneena Basin.

Data availability

- Regional data for Paterson South TEMPEST AEM Survey consisting of one kilometre (west) and two kilometre (east) line spacings are available as a free data download or from the Geoscience Australia Sales Centre.
- Regional data for Paterson North TEMPEST AEM Survey consisting of one kilometre, two kilometre and six kilometre line spacings are available as a free data download or from the Geoscience Australia Sales Centre.

Acknowledgements

Geoscience Australia sincerely thanks the following contributors

Aditya Birla Minerals – Birla Nifty Operations
Consolidated Minerals – Woodie Woodie Operations
Cameco
Cauldron Energy
Geological Survey of Western Australia
Geophysics Group at Geoscience Australia
Martu People
Mega Uranium
Newcrest Mining Limited - Telfer Operations
Rio Tinto
Western Areas
The Western Desert Land Aboriginal Corporation